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Comparison between two devices for measuring hip joint motions

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Objective : To compare the reliability of measurements of hip motions obtained with two instruments, an electronic inclinometer and a two-arm goniometer, and to investigate whether the two instruments, and different body positions, produce the same measurement data.
Methods : Maximal active and passive hip movements were measured simultaneously with both instruments, in nine subjects during 10 consecutive measurements at short intervals.
Results : Intra-observer variability was lower with the inclinometer in measurements of passive hip rotations. The two instruments showed equal intra-observer variability for hip movements in general. The inclinometer showed lower inter-observer variability in the measurements of active internal rotation. More rotational movement was measured with the two-arm goniometer; more extension and flexion with the inclinometer. Also, more rotational movement was found in the prone position compared to sitting and supine positions.
Conclusions : The inclinometer is more reliable in measurements of hip rotation. For hip movements in general the two-arm goniometer is just as accurate when used by only one observer. The two instruments, and some positions, are not interchangeable during consecutive measurements.

Introduction

Limitations of hip motion are important signs of hip disease, such as osteoarthritis,[1,2] and accurate measurement of range of motion is essential for monitoring hip disease and for the evaluation of treatment. Reliable and comparable measurements are especially important in research projects. Nevertheless, there is no universally accepted standard device for measuring hip joint motion.[3]

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Two devices are available for measuring joint motion in a clinical setting: a two-arm goniometer and an inclinometer. Of these two instruments, the goniometer is most frequently used,[3,4] but the inclinometer is claimed to have greater reliability.[4] Many studies have shown the superiority of the inclinometer in measuring complex motions such as movements of the spine.[5–7] However, only a few studies have compared the reliability of inclinometers and goniometers for measuring joint motion in the extremities.[8,9] None of these studies focused on the hip joint.

An inclinometer is driven by gravity, making measurements in the horizontal plane impossible with this device. Hip rotation and abduction and

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adduction with the patient lying supine, as recommended by the American Academy of Orthopaedic Surgeons (AAOS),[10] cannot be measured with an inclinometer. Most studies on normal range-of-motion (reference values) followed the AAOS methods of measurements and have used a two-arm goniometer.[11–15]

When using a new instrument it should be verified whether it measures the same range-of-motion as the traditional instrument. For some movements, measurements with the inclinometer entail different positioning of the subject, and it is important to establish what influence these positions have on measurement outcomes. The present study was set up to address these two topics. In addition, it aimed to clarify which of the two instruments provides the most reliable measurements of hip motion in a clinical setting by determining the intra- and inter-observer variabilities of both instruments.

Methods

Subjects and observers

The subjects were nine healthy persons (2 males, 7 females); age range 21–43 years. All volunteers were familiar with the purpose of the study. Ten medically educated observers, with previous experience in using a two-arm goniometer, received identical instruction and training in the procedures and measurement techniques of the two instruments before the study.

Material

The two-arm goniometer (Enraf Nonius, Delft, The Netherlands) is a plastic long-armed (50 cm) instrument with a 180° scale marked in one-degree increments (Figure 1). The inclinometer, the EDI-300 (Cybex, New York, USA), is an electronic digital device with a measuring unit (which is placed on the moveable part of the body) and a display unit containing a microprocessor that processes and displays the range of motion in one-degree increments. This instrument also has an extra 'long bone' attachment for additional stabilization of the measuring unit on the leg when testing hip motion (Figure 1).

Procedure

Systematic differences between instruments and positions

Simultaneous measurement with both instruments enabled systematic differences between measurements obtained with both devices to be studied. The influence of the different positions of the subject was assessed by measuring the internal and external rotation in three positions (lying prone, sitting and lying supine), and the abduction and adduction in two positions (lying on the side and lying supine).

Intra-observer variability

A 'test–retest' design was used with separate tests at short intervals; this type of test is accepted as the most accurate design for assess-

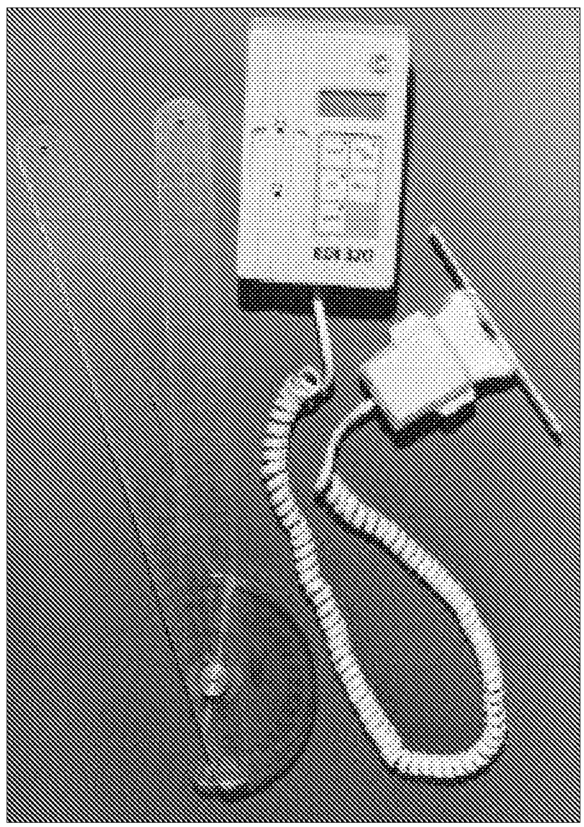

Figure 1 The two-arm goniometer (left) and the electronic inclinometer (right). The measuring unit of the inclinometer is extended with the 'long bone' attachment.

ment of the reliability of instruments.[16] To study intra-observer variability, one observer measured the various hip movements 10 times consecutively in the nine subjects. The inclinometer and two-arm goniometer were removed and repositioned between each measurement. The observer was blinded for the results of the electronic inclinometer. The observer ensured that the alignment of the two-arm goniometer was correct, kept the goniometer fixed in this position, and read the results of the measurements.

Inter-observer variability

To examine the variability between observers, 10 different observers measured the internal and external rotation of nine subjects in sitting position. The measurements were made simultaneously with the inclinometer and the goniometer at short intervals (test–retest design). The same procedure was followed as used in assessing the intra-observer variability.

Movements in the horizontal plane can only be measured with the two-arm goniometer. Therefore, abduction and adduction and the internal and external rotation with the subject lying supine were measured with the goniometer but not with the inclinometer. Abduction and adduction were measured with the inclinometer with the subject lying on his or her side (lateral decubitus position); measurements in this position were not possible with the goniometer because the arm of this instrument is too long for exact alignment over the anatomical landmarks. Internal and external rotation with the subject sitting as well as lying prone, and flexion (lying supine) and extension (lying prone), were all measured simultaneously with the goniometer and the inclinometer. In all movements maximal passive and active measurements were obtained, except for extension and abduction, which were only measured passively (due to muscle fatigue during the active movements). Detailed information about the alignment of the instruments and the limb positioning during the measurements is given in the Appendix.

Data analyses

Differences in measurement between the different positions and between the two instruments were tested separately for each movement by means of ANOVA. Fixed effects in the model were: instruments, position, active versus passive movements; random effect: subjects. Ten measurements taken with one instrument in one position from one subject were considered repeated measurements.

In order to estimate the variability per instrument we used ANOVA (for each instrument separately and for active and passive separately) as recommended for experiments with more than two repeated measurements.[17] This was done for each movement separately and also for all movements in one model. The square root of the mean square error is an estimate of the intra-observer variability (within observer standard deviation (SD)). The ratio of the two means square errors (obtained separately for the two instruments) has under H_0 an F distribution with degrees of freedom corresponding to the degrees of freedom of the two mean square errors. A p-value of 0.05 was considered statistically significant.

A similar procedure was followed to determine the inter-observer variability.

Results

Systematic differences between measurements and positions

Table 1 shows the mean outcomes of all movements measured. There were significant differences in measurement outcome in several movements that were measured with both instruments. Significantly ($p = 0.003$) more flexion and extension with the inclinometer was observed. Significantly ($p = 0.016$) more external rotation in the sitting position was measured with the two-arm goniometer. In the prone position more external rotation ($p < 0.001$) was measured with the goniometer.

The position of the subject resulted in significant differences in the outcomes of measurements. More internal and external rotation was measured in the prone position compared to the sitting and supine positions ($p < 0.001$). Adduction was increased in the lateral decubitus position compared to adduction in the supine position ($p = 0.006$). Whether this difference in adduction depends on the position or the instrument is not clear. No significant differences were found between measurement of the internal and external rotation in sitting and supine positions, and between passive abduction in lateral decubitus and supine positions.

Intra-observer variability

No significant differences in intra-observer variability were found when comparing measurements obtained with the two instruments when testing equality in overall variability for all movements at once. When testing equality in variability for each movement separately, however, significant differences were found. In measurements of passive rotations the variability was lower when using the inclinometer. In active rotation the results were contradictory; measurements of external rotation lying prone and internal rotation in sitting showed lower variability with the inclinometer but internal rotation in sitting showed lower variability with the two-arm goniometer. Table 2 gives the *p*-values for the tests of equality of intra-observer variance in measurements with the two instruments, the within-observer standard deviation (SD) of the different hip movements in the nine subjects, and the overall standard deviation within observers.

Inter-observer variability

Table 3 presents *p*-values for the tests of equality of inter-observer variance in measurements with the two instruments, and the between observers SD for external and internal rotation separately as well as the overall SD for these movements. In active internal rotation a significant difference was found, i.e. the SD was significantly smaller with the inclinometer. Overall variability for internal and external rotation together was also lower with the inclinometer.

Discussion

Systematic differences between instruments and positions

An important observation in the present study was that the two devices do not measure the same range of motion; this means that the instruments are not interchangeable for subsequent measurements. In addition, range of motion measured with the inclinometer cannot always be compared with reference values of normal range of motion measured with the two-arm goniometer.

The dissimilarities in outcomes found in the different positions have the same consequences.

Table 1 Mean range of motion (ROM) in degrees in nine subjects measured with the electronic inclinometer and with the two-arm goniometer in different positions

	Active mean ROM		Passive mean ROM	
	Two-arm goniometer	Electronic inclinometer	Two-arm goniometer	Electronic inclinometer
Extension	–	–	21.5	27.6
Flexion	116.1	120.5	126.6	132.0
Internal rotation				
Lying supine	36.0	32.0	39.9	37.5
Lying prone	46.3	44.2	53.2	50.4
Sitting	33.6	–	38.8	–
External rotation				
Lying supine	33.1	26.4	34.2	33.0
Lying prone	47.0	38.0	51.9	43.0
Sitting	33.9	–	37.6	–
Adduction				
Lying supine	19.2	–	17.1	–
Lateral decubitus position	–	28.7	–	28.7
Abduction				
Lying supine	38.0	–	43.2	–
Lateral decubitus position	–	–	–	48.5